A Reappraisal of the Stratigraphy of the upper Shoalhaven Group and lower Illawarra Coal Measures, southern Sydney Basin, New South Wales

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Recent mapping and reappraisal of previous work have clarified the stratigraphy and nomenclature of the upper Shoalhaven Group and lower Illawarra Coal Measures of the southern Sydney Basin. The interval between the Berry Siltstone and Illawarra Coal Measures is termed the Broughton Formation which can be subdivided in the Gerringong-Wollongong region where distinctive latite flows occur. In stratigraphic sequence the members of the Broughton Formation are Westley Park Sandstone (lowermost unit), Blow Hole Latite, Kiama Sandstone, Bumbo Latite, Jamberoo Sandstone, Saddleback Latite, Dapto Latite and Cambewarra Latite (uppermost unit). The Saddleback and Dapto Latite Members are considered to be separate flows which occur at similar stratigraphic positions below the Cambewarra Latite. The Pheasants Nest Formation of the Illawarra Coal Measures overlies the Broughton Formation and contains four latite members: Five Islands, Calderwood (new unit), Minumurra and Berkley.

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INTRODUCTION

The southern Sydney Basin contains Permian and Triassic marine and non-marine sedimentary rocks which were subjected to four phases of igneous activity between the Late Permian and the Late Oligocene (Carr and Facer, 1980). Permian rocks are subdivided into two groups, the lower of which comprises the marine strata of the Shoalhaven Group, the other consists of the overlying non-marine strata of the Illawarra Coal Measures. Diversity of opinion concerning the mode of emplacement, and the number, of Late Permian igneous rock-units which crop out in the Wollongong-Gerringong region (Fig. 1) has been a major factor in the lack of agreement on the stratigraphic status and relationships of many Late Permian units in the southern Sydney Basin. Remapping by the author has clarified the stratigraphic nomenclature of the upper Shoalhaven Group and lowermost Illawarra Coal Measures. Rationalization of this confused terminology prompts the present author to propose one new name and a number of changes in status. Important previously published stratigraphic schemes and the scheme proposed herein are shown in Fig. 2.

STRATIGRAPHIC SETTING

The Permian sequence in the southern Sydney Basin unconformably overlies earlier Palaeozoic strata. In the southern extremity of the basin minor coal measure sedimentation (Clyde Coal Measures) occurred as a lateral western equivalent to the shallow marine Conjola Sub-group. This latter unit is conformably overlain by the Wandrawandian Siltstone which in turn underlies the Nowra Sandstone. Boundaries between all the units in the lower Shoalhaven Group represent facies changes which are slightly diachronous. All of the units so distinguished appear to grade westwards into

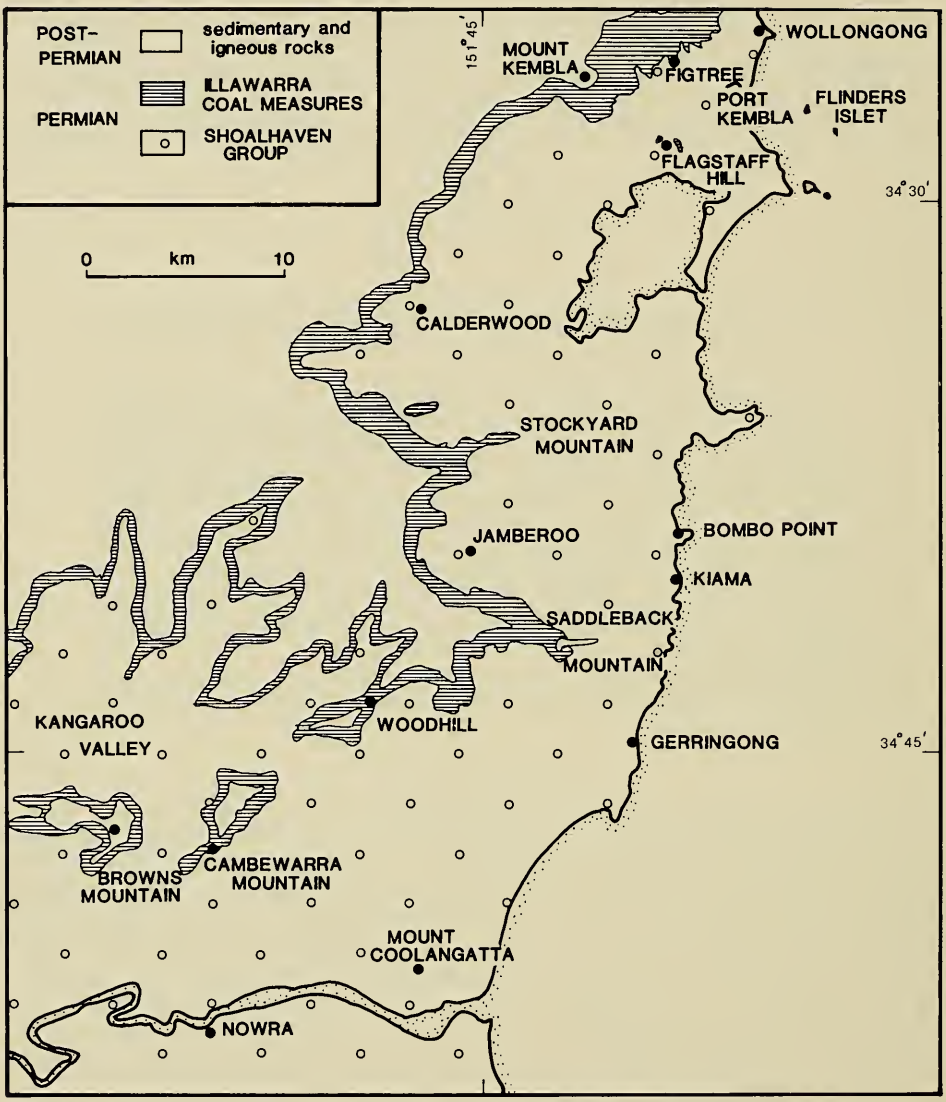

Fig. 1. Locality map and simplified geology of the Wollongong-Gerringong region.

the Megalong Conglomerate (McElroy *et al.*, 1969). The Berry Siltstone conformably overlies both the Nowra Sandstone and the Megalong Conglomerate.

Joplin *et al.* (1952) grouped the marine and igneous rocks between the Berry Siltstone and Illawarra Coal Measures into the Gerringong Volcanics and named the unit above the Berry Siltstone the Broughton Tuff. They considered the Broughton Tuff to be divisible in the Gerringong-Wollongong region because of the presence of distinctive extrusive units. Rose (1966) included the Gerringong Volcanics as a Subgroup of the Shoalhaven Group. He recognized the Budgong Sandstone Member (of the Berry Formation) which he considered was stratigraphically partially equivalent to the Broughton Tuff. The distinctive igneous units near the top of the Shoalhaven

Group had formation status (Harper, 1915; Joplin *et al.*, 1952; Rose, 1966) but were termed members of the "Gerringong volcanic facies" by Bowman (1970, 1974). Sandstones between these igneous rocks have been described as formations (Harper, 1915; Rose, 1966) and as members (Joplin *et al.*, 1952; Bowman, 1970, 1974). West of the volcanic flows the interval between the Berry Siltstone and the Illawarra Coal Measures has also had a varied nomenclature including Broughton Tuff (Joplin *et al.*, 1952; Rose, 1966) and Budgong Sandstone (Bowman, 1970, 1974). Recent discussions on the ages of the marine faunas of the Shoalhaven Group may be found in Runnegar and McClung (1975) and McClung (1978).

The Shoalhaven Group is conformably overlain by the non-marine deposits of the Pheasants Nest Formation which is the lowermost unit of the Illawarra Coal Measures. Harper (1915), Joplin *et al.* (1952) and Bowman (1970, 1974) have recognized two distinctive igneous rock-units within the Pheasants Nest Formation.

Broughton Formation

In the present study the interval between the Berry Siltstone and the top of the Shoalhaven Group is termed the Broughton Formation which is subdivided into three sandstone members and five latite members in the Wollongong-Gerringong area.

The basal unit of the formation is the Westley Park Sandstone Member which conformably and gradationally overlies the Berry Siltstone at Mount Coolangatta (Fig. 1). The nature of this boundary was recognized by Card and Jaquet (1903) and McElroy *et al.* (1969). Subdivision of the formation is entirely based on and, indeed, is only made possible by the presence of interbedded latites. Problems in stratigraphic terminology have arisen due to restriction, in large part, of some volcanic flows to the coastal strip. The top of the Cambewarra Latite Member or equivalent boulder horizon marks the top of the Shoalhaven Group (Harper, 1915, p. 223) and thus the top of the Broughton Formation.

The name Broughton is chosen by the author in preference to Gerringong (equal priority) as the former proposal appears to reflect most closely the original intention of the nomenclature proposed by Jaquet *et al.* (1905, plate VII). In addition, usage of the name Broughton Formation allows the term Gerringong volcanics to be used as an *informal* name for the succession characterized by volcanic flows in the upper Shoalhaven Group and lower Illawarra Coal Measures. The term Budgong is rejected since it was introduced by Rose (1966) long after both Broughton and Gerringong had been initially defined (Joplin *et al.*, 1952).

Westley Park Sandstone Member. Jaquet *et al.* (1905) defined the Westley Park Tuffs which were renamed the Westley Park Tuff Member, Westley Park Sandstone and Westley Park Sandstone Member by Joplin *et al.* (1952), Raam (1968) and Bowman (1970, 1974) respectively. The unit gradationally and conformably overlies the Berry Siltstone at Mount Coolangatta and is conformably overlain by the Blow Hole Latite Member (Fig. 2). The unit has been described by Raam (1968, 1969) as a shallow marine arenite with minor siltstone and conglomerate, and attains a maximum thickness of 45 m.

Blow Hole Latite Member. Jaquet *et al.* (1905) named the Blow Hole Flow which was renamed the Blow Hole Latite by Joplin *et al.* (1952). The member is stratigraphically the lowest of the Permian flows in the Kiama-Wollongong region with present outcrops confined to a narrow zone from Kiama southwards for 22 km to Mount Coolangatta (Fig. 1). A maximum exposed thickness of 50 m occurs on the eastern side of Saddleback Mountain (Fig. 1). Bowman (1974) has reported that the unit consists of three flows.

HARPER (1915)

GROUP	FORMATION
UPPER COAL MEASURES	
	Minumurra Flow
	Berkley Flow
UPPER MARINE SERIES	Cambewarra Flow
	Dapto-Saddleback Flow
	Five Islands Flow
	Jamberoo Tuffs
	Bumbo Flow
	Kiama Tuffs
	Blow Hole Flow
	Westley Park Tuffs
	Crinoidal Shales
	Nowra Grits
	Conjola Conglomerates
	Ulladulla tuffaceous mudstones and sandstones

JOPLIN et al. (1952)

GROUP	FORMATION	MEMBER
ILLAWARRA COAL MEASURES		
	Minumurra Latite	
	Berkley Latite	
GERRINGONG VOLCANICS	Cambewarra Latite	
	Saddleback Latite	
	Broughton Tuff	Jamberoo Tuff Member
	Bumbo Latite	
		Kiama Tuff Member
	Blow Hole Latite	Rifle Range Tuff Member
		Westley Park Tuff Member
SHOALHAVEN GROUP	Berry Shale	
	Nowra Sandstone	
	Wandrawandian Siltstone	
	Undifferentiated	

ROSE (1966)

GROUP	SUB-GROUP	FORMATION	MEMBER
ILLAWARRA COAL MEASURES			
		Minnamurra Latite	
		Berkley Latite	
SHOALHAVEN GROUP	GERRINGONG VOLCANICS	Cambewarra Trachyte	
		Dapto-Saddleback Latite	
		Broughton Tuff: Jamberoo Tuff	
		Bumbo Latite	
		Klama Tuff	
		Blow Hole Latite	
		Westley Park Tuff	
		Berry Formation	Budgong Sandstone Member
		Nowra Sandstone	
		Wandrawandian Siltstone	
		Conjola Formation	

BOWMAN (1974)

GROUP	SUB-GROUP	FORMATION	MEMBER
ILLAWARRA COAL MEASURES	CUMBERLAND SUB-GROUP	Pheasants Nest Formation	
			Gerringong volcanics facies: Berkeley Latite Member
			Minnamurra Latite Member
SHOALHAVEN GROUP		Budgong Sandstone	Broughton Sandstone Member: Dapto Latite Member
			Cambewarra Latite Member
			Saddleback Latite Member
			Jamberoo Sandstone Member
			Bumbo Latite Member
			Kiama Sandstone Member
			Blow Hole Latite Member
			Westley Park Sandstone Member
		Berry Siltstone	
		Nowra Sandstone	
		Wandrawandian Siltstone	
	CONJOLA SUB-GROUP		

PRESENT STUDY

GROUP	SUB-GROUP	FORMATION	MEMBER
ILLAWARRA COAL MEASURES	CUMBERLAND SUB-GROUP	Pheasants Nest Formation	
			Berkley Latite Member
			Minumurra Latite Member
			Calderwood Latite Member
			Five Islands Latite Member
SHOALHAVEN GROUP		Broughton Formation	Cambewarra Latite Member
			Dapto Latite Member
			Saddleback Latite Member
			Jamberoo Sandstone Member
			Bumbo Latite Member
			Kiama Sandstone Member
			Blow Hole Latite Member
			Westley Park Sandstone Member
		Berry Siltstone	
		Nowra Sandstone	
		Wandrawandian Siltstone	
	CONJOLA SUB-GROUP	Snapper Point Formation	
		Pebbley Beach Formation	
		Wasp Head Formation	

Fig. 2. Important previously published stratigraphic schemes and nomenclature proposed herein.

The unit contains pillows and breccias consisting of latite in a sedimentary matrix showing soft-sediment deformation structures. Both pillows and breccias have been described in detail by Raam (1964, 1969) who considered that these features indicate that the Blow Hole Latite Member was contemporaneous with the associated sedimentary rocks. Since the sandstone units both above and below the Blow Hole Latite Member contain sedimentary structures and an abundant fauna indicative of a near-shore marine environment (Raam, 1968), the Blow Hole Latite Member is interpreted as a near-shore, submarine flow on to wet, unconsolidated sediments. Locally the flow intruded into the sediments to show restricted intrusive contacts.

Kiama Sandstone Member. This unit conformably overlies the Blow Hole Latite Member and was defined as the Kiama Tuff by Jaquet *et al.* (1905). Joplin *et al.* (1952) renamed the unit the Kiama Tuff Member and Raam (1968, 1969) referred to this arenite as the Kiama Sandstone. A maximum thickness of 53 m is developed at Jamberoo (Fig. 1). The faunal assemblages indicate deposition in a shallow marine environment (Raam, 1968).

Bumbo Latite Member. The Bumbo Flow which overlies the Kiama Sandstone Member was originally named by Jaquet *et al.* (1905) and was renamed the Bumbo Latite by Joplin *et al.* (1952). This unit is one of the most extensive and most voluminous Permian flows of the southern Sydney Basin and outcrops over a total area of approximately 240 km^2. A maximum thickness of 150 m is developed at Saddleback Mountain (Fig. 1). Bowman (1974) has reported that the unit consists of three flows in some areas.

The base of the Bumbo Latite Member is well exposed at Bombo Point where the contact is either sharp or is marked by a basal breccia up to 3 m thick. Sub-vertical to vertical pipe-like masses of breccia, 1 to 10 m in diameter, occur at many localities. Contacts between the breccia pipes and the surrounding latite are normally sharp, with a decrease in the size and abundance of vesicles in the latite away from the core of the breccia zone. Both the basal breccia and pipe-like masses of breccia consist of clasts of latite in a matrix of sedimentary material and cement of zeolite and hematite. The sedimentary material is indistinguishable from the underlying Kiama Sandstone Member and in places shows contorted bedding which has been interpreted by Raam (1964) as due to soft-sediment deformation. The breccias appear to have formed as a result of the interaction of magma with the underlying water-saturated sediment. Steam produced at this contact fragmented the base of the lava flow and, in some areas, dragged up wet sediment into the overlying volcanic rock (Raam, 1964).

Jamberoo Sandstone Member. The Jamberoo Sandstone Member conformably overlies the Bumbo Latite Member and is conformably overlain by the Saddleback Latite Member. Jaquet *et al.* (1905) defined the unit as the Jamberoo Tuffs but Joplin *et al.* (1952) changed the name to the Jamberoo Tuff Member. Subsequently Raam (1968) renamed the unit the Jamberoo Sandstone. A maximum thickness of 155 m is developed at Jamberoo (Jaquet *et al.*, 1905).

Saddleback Latite Member. Nomenclature of the Saddleback Latite Member has been varied and problematical. The extrusion was defined as the Saddleback Flow by Jaquet *et al.* (1905) and renamed the Dapto-Saddleback Flow by Harper (1915) who considered that the two unconnected outcrops in the vicinity of Port Kembla in the north and Saddleback Mountain in the south resulted from the same flow. Joplin *et al.* (1952) accepted Harper's opinion and redefined the two outcrops as one unit — the Saddleback Latite. Bowman (1970, 1974) considered that the Port Kembla and Saddleback Mountain outcrops resulted from two flows at different stratigraphic levels. Thus Bowman (1970, 1974) recognized the Saddleback Latite Member in the south, and the

Dapto Latite Member in the north and he considered the latter unit to *overlie* the Cambewarra Latite Member. In the present investigation the Saddleback and Dapto Latite Members are considered to be separate flows which occupy similar stratigraphic positions *below* the Cambewarra Latite Member. Stratigraphic relations between these units are discussed in a later section of this paper.

Outcrops of the Saddleback Latite Member extend around the Illawarra escarpment from the southern side of Saddleback Mountain to Woodhill and the eastern limit of Kangaroo Valley. The unit does not occur on the northern slopes of Saddleback Mountain but crops out further to the north along the scarp on the southern flanks of Stockyard Mountain. The maximum thickness of 35 m is developed on the southern side of Saddleback Mountain.

Harper (1915) interpreted the Saddleback Latite Member as a submarine extrusion. This view was supported by Lowder (1964) who found probable pillow structures at several localities. Also, the presence of vesicles near the top of the unit is suggestive of emplacement at, or near, the earth's surface. Thus the Saddleback Latite is interpreted as being a submarine lava flow.

Dapto Latite Member. All outcrops of the Dapto Latite Member occur in the vicinity of Port Kembla within an area of approximately 100 km^2. Flagstaff Hill (Fig. 1) and its vicinity provide the most extensive and thickest (85 m) outcrop and the unit thins to the north, west and southwest away from this area.

Various features present in the Dapto Latite Member and surrounding sedimentary rocks have been interpreted as indicating that the unit is a flat-topped laccolith intruded into unconsolidated Permian marine sedimentary rocks (Wilshire and Hobbs, 1962). However, since the time of publication of their article, drilling and extensive road-making activities by the New South Wales Department of Main Roads have provided access to much more information regarding the mode of emplacement of the Dapto Latite Member. As the drill-core is not available (lost or destroyed), the borehole logs of Cook (1966) were used to provide sub-surface data on the Dapto Latite Member. Integration of the data from outcrops and the boreholes provides the following interpretation:

(i) The top of the Dapto Latite Member is uneven and is overlain by approximately 3 m of sandstone containing abundant feldspar crystals and fragments of the underlying latite. The fragments of igneous rock are usually rounded, are concentrated into particular horizons, and are isolated from the main mass of igneous rock. The clasts of the Dapto Latite Member in the sedimentary rocks are undoubtedly detrital in origin.

(ii) Although fine-scale individual horizons are difficult to follow in outcrop, near horizontal bedding (dip 3° to north-northwest) is apparent in the sedimentary rocks above the Dapto Latite Member. Apart from localized draping of bedding over the detrital latite clasts there is no evidence of bedding distortion that would be expected to accompany the intrusion of a large mass of igneous rock into unconsolidated sediments.

(iii) The Dapto Latite Member consists of two flows which, over much of the region, are separated by a breccia. The borehole logs of Cook (1966) describe the breccia as a complex succession of sandstone, siltstone and blocks of latite ranging from 5 cm to 3 m in vertical extent. The sedimentary rocks contain clasts of feldspar and latite and, apart from steeply inclined contacts with the latite blocks, are horizontally bedded with some cross-bedding.

Cambewarra Latite Member. The Cambewarra Latite Member is the uppermost unit of the marine Shoalhaven Group and is the most extensive of the Permian extrusions in

the southern Sydney Basin. A maximum thickness of 70 m occurs at Woodhill. The flow has a pronounced physiographic expression and forms steep slopes or cliffs extending from Browns Mountain to the northern side of Stockyard Mountain (Fig. 1). Between Stockyard Mountain and Wollongong, the Cambewarra Latite Member is represented by a boulder horizon (Harper, 1915).

Numerous amygdules and vesicles near the top of the Cambewarra Latite Member indicate that crystallization occurred at or near the earth's surface. A subaqueous, extrusive mode of emplacement is indicated by the presence of pillow structures with an inter-pillow matrix of shale and sandstone (Lowder, 1964). Marine fossils both below and within the equivalent unit suggest deposition in a marine environment (Harper, 1915, p. 223).

A boulder horizon containing numerous vesicular and amygdaloidal clasts of the Cambewarra Latite Member in a volcarenite matrix extends beyond the northern limit of the flow to Wollongong. Harper (1915) considered that the boulder horizon originated by contemporaneous erosion and deposition of clasts of Cambewarra Latite Member by a strong marine current flowing towards the north. The direction of the current was deduced from the absence of the boulder horizon south of Saddleback Mountain and the decrease in size of the clasts in the northerly direction whereas marine deposition is indicated by the presence of marine fossils in the horizon. A southerly source is consistent with recent work on the sedimentology of the upper part of the Shoalhaven Group and lower part of the Illawarra Coal Measures (Bowman, 1974; B. G. Jones, *pers. comm.* 1980). Harper (1915) traced the boulder horizon as far north as the Wollongong Water Supply Service Reservoir which was situated 5 km north-northeast of Flagstaff Hill (Fig. 1). Excavation of a 30 m deep cutting through the western flank of Flagstaff Hill by the New South Wales Department of Main Roads has exposed a conglomerate 3 to 5 m stratigraphically above the Dapto Latite Member. The conglomerate, which contains rounded clasts of amygdaloidal igneous rock in an arenite matrix, is considered by the author to represent the boulder horizon in this region.

Pheasants Nest Formation

The Broughton Formation is conformably overlain by non-marine deposits of the Pheasants Nest Formation at the base of the Cumberland Sub-group of the Illawarra Coal Measures (Fig. 2). Where the Cambewarra Latite Member or the equivalent boulder horizon is lacking the contact between the Shoalhaven Group and Illawarra Coal Measures is transitional (Wilson, 1969, p. 372). Sedimentary strata of the Pheasants Nest Formation consist of interbedded sandstone, siltstone and shale which lack marine fossils but contain fossil tree stumps, logs and plants. Only the four latite members interbedded with these sedimentary strata are described here.

Five Islands Latite Member. The Five Islands Flow was named by Harper (1915) but for consistency of nomenclature is renamed herein the Five Islands Latite Member. The unit is very restricted in outcrop and occurs only on Flinders Islet which is the northernmost of the Five Islands (Fig. 1). Pillow structures up to 1 m in diameter indicate a subaqueous, extrusive mode of emplacement.

As the Five Islands Latite Member is the only unit which crops out on Flinders Islet, the stratigraphic position of the flow is problematical. The sedimentary strata of the Broughton Formation on the mainland nearest to Flinders Islet are almost horizontal with a slight dip (2° to 3°) towards the northwest. Evidence for major faulting is lacking. Also, the islands south and southeast of Flinders Islet are composed of Dapto Latite Member. Assuming no major faulting occurs between Flinders Islet

and the mainland or the other islands, the Five Islands Latite Member must be stratigraphically above the Dapto Latite Member. A lower limit on the stratigraphic separation between the Dapto Latite Member and Five Islands Latite Member cannot be inferred due to the lack of outcrops in proximity to Flinders Islet. However, an upper limit on the stratigraphic separation may be inferred from the regional dip of 3° to the northwest and the minimum distance between outcrops of the Five Islands and Dapto Latite Members. The nearest outcrop of the Dapto Latite Member is Bass Islet which is 1700 m southeast of Flinders Islet (i.e. down dip from the Five Islands Latite Member) and implies a maximum stratigraphic separation of 90 m. Thus the Five Islands Latite Member is taken to occur in the lower part of the Illawarra Coal Measures. The Calderwood, Minumurra and Berkley Latite Members occupy similar stratigraphic positions to that of the Five Islands Latite Member but the exact relationship between the former three units and the Five Islands Latite Member is unknown.

On the basis of similarity of petrography to some samples from Kiama and Jamberoo, Chalmers (1941) mapped Flinders Islet as a remnant of the Bumbo Latite Member. However, the Five Islands Latite Member is geochemically distinct from the other latites (Carr, unpublished data) and on the basis of the inferred stratigraphic relationships outlined previously, Flinders Islet is considered to be composed of the Five Islands Latite Member and not the Bumbo Latite Member.

Calderwood Latite Member. The Calderwood Latite Member has not been recognized previously. The name is here proposed for the unit which crops out around Calderwood (Fig. 1) and is 3 m stratigraphically above the Cambewarra Latite Member (i.e. within, and near the base of, the Illawarra Coal Measures). The Calderwood Latite Member is restricted in outcrop area and extends discontinuously from the north-eastern side of Stockyard Mountain towards the north-northwest for a distance of 9 km.

A maximum thickness of 38 m occurs near Calderwood (GR 908728 Robertson 1:25,000 Topographic Sheet 9028-IV-N First Edition) but the unit thins rapidly towards the north, south and west. A probably extrusive mode of emplacement is indicated by the high proportion of volcaniclastic material in the sedimentary rocks both above and below the unit. The volcaniclastic material above and below the Calderwood Latite Member is possibly equivalent to Bowman's (1974) Tappitallee Mountain Tuff Member.

The outcrop on the northeastern side of Stockyard Mountain (GR 958685 Albion Park 1:25,000 Topographic Sheet 9028-I-N First Edition) corresponds to the outcrop which Jaquet *et al.* (1905) and Lowder (1964) mapped as Saddleback Latite Member occurring at the top of the Cambewarra Latite Member. These authors were aware of the anomalous stratigraphic position but considered that the Saddleback Latite Member at this locality formed a topographic high at the time of eruption of the Cambewarra Latite Member. The present investigation, however, indicates that the outcrop on the northeastern side of Stockyard Mountain is separated from the underlying Cambewarra Latite Member by 3 m of sandstone and shale of the Illawarra Coal Measures.

Bowman (1970, 1974) did not record either the Saddleback Latite Member underlying the Cambewarra Latite Member between Saddleback and Stockyard Mountain, or the Calderwood Latite Member on the northeastern side of Stockyard Mountain. However, the other outcrops of the latter unit were mapped as Dapto Latite Member (Bowman, 1970, 1974). These outcrops occur above the Cambewarra Latite Member and thus he concluded that the Dapto Latite Member is stratigraphically

above the Cambewarra Latite Member. In spite of Harper's (1915) recognition of the Cambewarra boulder bed as far north as Wollongong, Bowman did not mention the possibility of another flow which was stratigraphically above the Cambewarra Latite Member, and which cropped out in the Calderwood region.

Minumurra Latite Member. Jaquet *et al.* (1905) defined the Minumurra Flow which was subsequently renamed the Minumurra Latite (Joplin *et al.*, 1952). The incorrect name Minnamurra Latite has also been used extensively (e.g. Lowder, 1964; Raam 1969; Bowman, 1970, 1974). The unit occurs approximately 40 m above the base of the Illawarra Coal Measures and extends as a discontinuous sheet from the northern side of Saddleback Mountain to a point 15 km west of Port Kembla. A maximum thickness of 35 m occurs at Minnamurra River.

The base of the Minumurra Latite Member is even but the top of the unit undulates by up to 0.5 m in a horizontal distance of 3 m. Horizontally-bedded sandstones, shales and siltstones fill the depressions in the upper surface and individual sedimentary units are thicker in the depressions than over the accompanying ridges (Lowder, 1964) (GR 904647 Kangaroo Valley 1:25,000 Topographic Sheet 9028-IV-S First Edition). An extrusive mode of emplacement is supported by the occurrence in joints near the top of the unit of sedimentary material lithologically different from the sedimentary rocks overlying the Minumurra Latite Member (Lowder, 1964). No evidence in support of an intrusive mode of emplacement has been found previously or in the present study. Since the Minumurra Latite Member occurs within the Illawarra Coal Measures, the unit is considered to be an extrusion which erupted on to the Permian land surface or into a shallow subaqueous environment.

Berkley Latite Member. Harper (1915) defined the Berkley Flow which was renamed the Berkeley Latite (McElroy, 1952), and the Berkley Latite (Joplin *et al.*, 1952). The incorrect spelling Berkeley has been used in many publications (e.g. McElroy, 1952; Raam, 1969; Bowman, 1970, 1974).

The base of the unit ranges between 15 and 40 m above the top of the Shoalhaven Group and thus occurs at approximately the same stratigraphic level as the Minumurra Latite Member. This variation in stratigraphic position possibly reflects the palaeotopography. The Berkley Latite Member has been considered to be intrusive (McElroy, 1952) and extrusive (Harper, 1915; Rose, 1966; Raam, 1969; Bowman, 1970, 1974). The latter conclusion is supported by the present study for the following reasons:

(i) clasts of Berkley Latite Member occur in the sandstone immediately above the unit at Mount Kembla (GR 005876 Wollongong 1:25,000 Topographic Sheet 9029-II-S First Edition);

(ii) apart from localized draping of the bedding over the latite clasts, the sandstone above the Berkley Latite Member shows no evidence of distortion of bedding as would be expected to accompany intrusion of a large mass of igneous rock into unconsolidated sediments (GR 012869 Wollongong 1:25,000 Topographic Sheet 9029-II-S First Edition); and

(iii) in the Figtree region, the Berkley Latite Member consists of two flows separated by approximately 3 m of sedimentary rocks of the Illawarra Coal Measures (GR 026875 Wollongong 1:25,000 Topographic Sheet 9029-II-S First Edition).

The features described and cited as evidence for emplacement as a sill (McElroy, 1952) possibly represent localized intrusive contacts produced by restricted intrusion of the flow into unconsolidated sediments. The flow has a maximum thickness of approximately 35 m in the Figtree region and thins to the north and southwest.

Stratigraphic Relationships between the Dapto and Saddleback Latite Members

Harper (1915) considered the Dapto Latite Member to be a northern extension of the Saddleback Latite Member. Since there is no evidence of continuity between the outcrops at Saddleback Mountain and Port Kembla, and since the thickness of igneous rock decreases away from a maximum for *each* area, the units are considered to have been separate flows.

The top of the Cambewarra Latite Member or the equivalent boulder horizon marks the top of the marine Shoalhaven Group (Harper, 1915). The contact between the Saddleback Latite Member and the overlying Cambewarra Latite Member is poorly exposed but no evidence has been found for the existence of sedimentary material between the two latites. By comparison, the Dapto Latite Member is separated from the Cambewarra boulder horizon by at least 3 m of sedimentary strata. Thus both the Dapto and Saddleback Latite Members occur within the Shoalhaven Group and occupy similar stratigraphic positions below the Cambewarra Latite Member or the equivalent boulder horizon. Assuming that deposition of the boulder horizon is essentially synchronous with eruption of the Cambewarra Latite Member, then either (i) the Saddleback and Dapto Latite Members are of the same age; or (ii) the Dapto Latite Member is slightly older than the Saddleback Latite Member. The implications of these equally plausible alternatives are discussed below.

Contemporaneous eruption of the Saddleback and Dapto Latite Members implies that subsequent to the extrusion of these flows and prior to the emplacement of the Cambewarra Latite Member and boulder horizon, sediment accumulated in the Port Kembla region whereas no deposition occurred in the vicinity of Saddleback Mountain. Alternatively, if the Dapto Latite Member is slightly older than the Saddleback Latite Member, sediment accumulated on top of the Dapto Latite Member prior to, and contemporaneously with, eruption of the Saddleback Latite Member. Subsequent to the eruption of the latter flow, the Cambewarra Latite Member and boulder bed were emplaced.

Summary and Conclusions

Strata of the upper Shoalhaven Group and lower Illawarra Coal Measures of the southern Sydney Basin have had a varied nomenclature. Reappraisal of previous work and recent mapping by the author have led to the recognition of nine distinct extrusive igneous rock-units in the Wollongong-Gerringong region. These flows provide a convenient basis for the subdivision of the strata of the upper Shoalhaven Group and lower Illawarra Coal Measures. The uppermost formation of the Shoalhaven Group is termed the Broughton Formation which contains five Latite Members — Blow Hole (lowermost unit), Bumbo, Saddleback, Dapto and Cambewarra (uppermost unit). The sedimentary strata between the Blow Hole and Bumbo Latite Members, and between the Bumbo and Saddleback Latite Members are known as the Kiama Sandstone Member and Jamberoo Sandstone Member respectively. Four Latite Members (Five Islands, Calderwood, Minumurra and Berkley) are recognized in the Pheasants Nest Formation of the Cumberland Sub-group of the Illawarra Coal Measures.

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